3D Propagation and Geoacoustic Inversion Studies in the Mid-Atlantic Bight

Kevin B. Smith
Code PH/Sk, Department of Physics
Naval Postgraduate School
Monterey, CA 93943
phone: (831) 656-2107   fax: (831) 656-2834   email: kevin@physics.nps.navy.mil
Award #: N0001499WR30120

LONG-TERM GOAL

Under the Shelf-Break Primer initiative, the Office of Naval Research sponsored a multi-year study of acoustic propagation in the region of the North Atlantic Bight off the coast of New Jersey. This region is of interest due to the combination of sloping bathymetry near the continental shelf and the strong oceanographic frontal features associated with the Gulf Stream. The general purpose of this project is to study the effects of the frontal region on acoustic propagation onto the shelf. Proposed here is a complementary study of propagation effects and data analysis. Specifically, the influence of three-dimensional propagation effects and their influence on the prediction of broadband measurements in similar oceanographic regions shall be addressed. Studies of two-dimensional propagation of broadband, explosive SUS will also be performed to examine correlations between geoacoustic properties and measured transmission loss. Results from this analysis will be considered in the context of geoacoustic inversions.

OBJECTIVES

To continue analysis of the Primer summer '96 acoustic data. This analysis will primarily focus on the influence of 3-D azimuthal coupling due to bathymetric features and ocean fronts near the shelf break of the mid-Atlantic Bight, and use of various data for geoacoutic inversion studies. The results of this analysis will provide guidance for the use of active and passive sonar systems near shelf break regions.

APPROACH

In FY99, I continued my analysis of the Primer summer 96 data sets. As before, issues to be considered included the influence of 3-D propagation on measured acoustic transmissions, both CW and broadband. This was done primarily by examining numerical results predicted by the limited azimuthal aperture technique I developed for the Monterey-Miami Parabolic Equation (MMPE) Model (Smith, 1999). The dominant mechanisms responsible for such azimuthal coupling were identified and quantified. The results of several analyses were compared and found to produce similar results. Signatures of such effects in the data were also scrutinized.

Additionally, the distinction between fully 3-D effects and those effects which are predictable by Nx2-D models were examined. A formal theory describing how Nx2-D models can produce 3-D propagation effects was developed by Prof. Frederick Tappert at the University of Miami.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE **3D Propagation and Geoacoustic Inversion Studies in the Mid-Atlantic Bight**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School,Department of Physics,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Examination of the depth-averaged energy measured on one of the VLA's due to the broadband SUS explosive sources was compared to numerical predictions. By varying the environmental and geoacoustic properties in a deterministic fashion, an intelligent search for geoacoustic properties could be performed. Results were compared with historical geoacoustic data sets and with the inversion values computed by Prof. James Miller at the University of Rhode Island (using a propagation model with a genetic algorithm approach).

WORK COMPLETED

Numerical analysis of significance of 3D propagation influences for this experimental configuration has been completed. Results from different numerical codes for various propagation tracks have been compared.

Broadband propagation over a synthetic, idealized ridge was computed using both the full 3-D propagation model and the Nx2-D counterpart. A theoretical foundation for the similarity between such predictions has been developed.

Numerical and data analysis of SUS signals for purposes of understanding influences of geoacoustic properties have been completed.

RESULTS

The numerical analysis showed that the dominant mechanism for 3-D azimuthal coupling in this region was typically the sloping bathymetry. This was particularly true for the steepest propagating paths (highest modes). However, for some propagation paths, the front caused by the interface between the warmer deep water on the Gulf Stream side and the colder shelf water became the dominant mechanism for horizontal refraction of the lowest grazing angle energy (lowest modes). In either case, this effect was quite small and may be considered insignificant relative to the uncertainty in determining the environment. The largest variation from direct radial propagation was on the order of 100 m over roughly 60 km. This was caused by the sloping bathymetry and was most significant when propagation was in the along-shelf direction.

Because the measure of the influence of 3-D effects is a comparison of 3-D results to the corresponding Nx2-D results, a more formal analysis of the two approaches was performed. Our results indicated that Nx2-D models can adequately predict horizontal refraction, if properly defined. By examining broadband propagation over an ideal, synthetic ridge, it was found that an Nx2-D model shows nearly the same horizontal refraction effects (Smith and Tappert, 1999).

The explosive SUS data received on the NW VLA was also examined in an attempt to determine the influence of geoacoustic and environmental properties on broadband propagation in the region. All of the data recorded from Run 1 and Run 4 of the SUS runs (Volak, et al., 1996) were examined. The data was converted to TL values by subtracting the empirical source levels obtained from Urick (1975). Average TL values over the depth of the array elements were computed to reduce the influence of modal structures. These TL values were compared to model results which considered range-independent and range-dependent SSP's as well as variations in bottom parameters including sound speed, sound speed gradient, density, and attenuation.

A bandwidth from 100 Hz to 1000 Hz was considered in the analysis. The results suggest that bottom attenuation dominates the absolute TL levels in this region. The sound speed at the water/bottom interface appear to dominate the average trend of TL versus frequency, and the range-dependent nature of the sound speed profiles seems to effect the smaller scale features of the TL dependence on frequency. The bottom sound speed gradient appeared to have minimal impact.

IMPACT/APPLICATION

The lack of significant azimuthal coupling effects observed is an important conclusion. This suggests that 2-D propagation models, and the sonar prediction systems based on such models, are satisfactory in many cases. Additionally, it was found that Nx2-D models can predict much of the 3-D acoustic field, including horizontal refraction. Thus, there appears to be no need to upgrade current systems to account for 3-D propagation effects. This is fortunate since such 3-D models are known to be much more computationally intensive than their 2-D counterparts.

The results from the analysis of the impact of various acoustic parameters on transmission loss over a wide bandwidth, coupled with other researchers efforts in developing geoacoustic inversion techniques, may help to improve inversion algorithms. By recognizing the distinct effects of the various parameters, one may hope to develop an "intelligent" search whereby entire features of the measured signal may influence the inversion scheme.

RELATED PROJECTS

1 - Brian Sperry and Jim Lynch (WHOI) have examined 3-D propagation effects in the Primer area using a hybrid ray-mode code. Their results are included in a publication.

2 - Fred Tappert (UM) has developed a theoretical description of the horizontal refraction which may be computed using Nx2-D models. We continue to examine the implications of this in our modeling efforts.

3 - Jim Miller (URI) continues studying methods for geoacoustic inversion using genetic algorithm techniques applied to the SUS explosive data.

REFERENCES

Carino, D. (1999). "Spectral Analysis of Energy and Transmission Loss Near the Mid-Atlantic Bight," M.S. Engineering Acoustics, September, 1999.

Volak, D., Brown, B., and Zeidler, E. (1996). "Shelf Break Primer 1996," NAVAIRWARCENACDIVPAX Technical Note TN-SBP-96.

Smith, K.B. (1999). "A three-dimensional propagation algorithm using finite azimuthal aperture," J. Acoust. Soc. Am. 106(6).

Smith, K.B. and Tappert, F.D. (1999). "Horizontal refraction and the uncoupled azimuth approximation," Proceedings of the 6th International Congress on Sound and Vibration, 5 - 8, July, 1999, Copenhagen, Denmark. (Invited Paper.)

Urick, R.J. (1975). *Principles of Underwater Sound*, Second Edition, New York, McGraw-Hill.

PUBLICATIONS

Carino, D. (1999). “Spectral Analysis of Energy and Transmission Loss Near the Mid-Atlantic Bight,” M.S. Engineering Acoustics, September, 1999.

Potty, G.R., Miller, J.H., Lynch, J.F., and Smith, K.B. (1999). “Tomographic mapping of sediments in shallow water,” J. Acoust. Soc. Am., 1999 (accepted).

Smith, K.B. (1999). “A three-dimensional propagation algorithm using finite azimuthal aperture,” J. Acoust. Soc. Am. 106(6).

Smith, K.B., Chiu, C.-S., Miller, C.W., D’Agostino, Sperry, B., and Miller, J.H. (1999). “Three-dimensional propagation effects near the Mid-Atlantic Bight,” J. Acoust. Soc. Am. (submitted).

Smith, K.B., Rojas, J.G., Miller, J.H., and Potty, G. (1999). “Geoacoustic inversions in shallow water using direct methods and genetic algorithm techniques,” J. Adv. Marine Sci. and Tech. Soc., 1999 (accepted).

Smith, K.B. and Tappert, F.D. (1999). “Horizontal refraction and the uncoupled azimuth approximation,” Proceedings of the 6th International Congress on Sound and Vibration, 5 - 8, July, 1999, Copenhagen, Denmark. (Invited Paper.)